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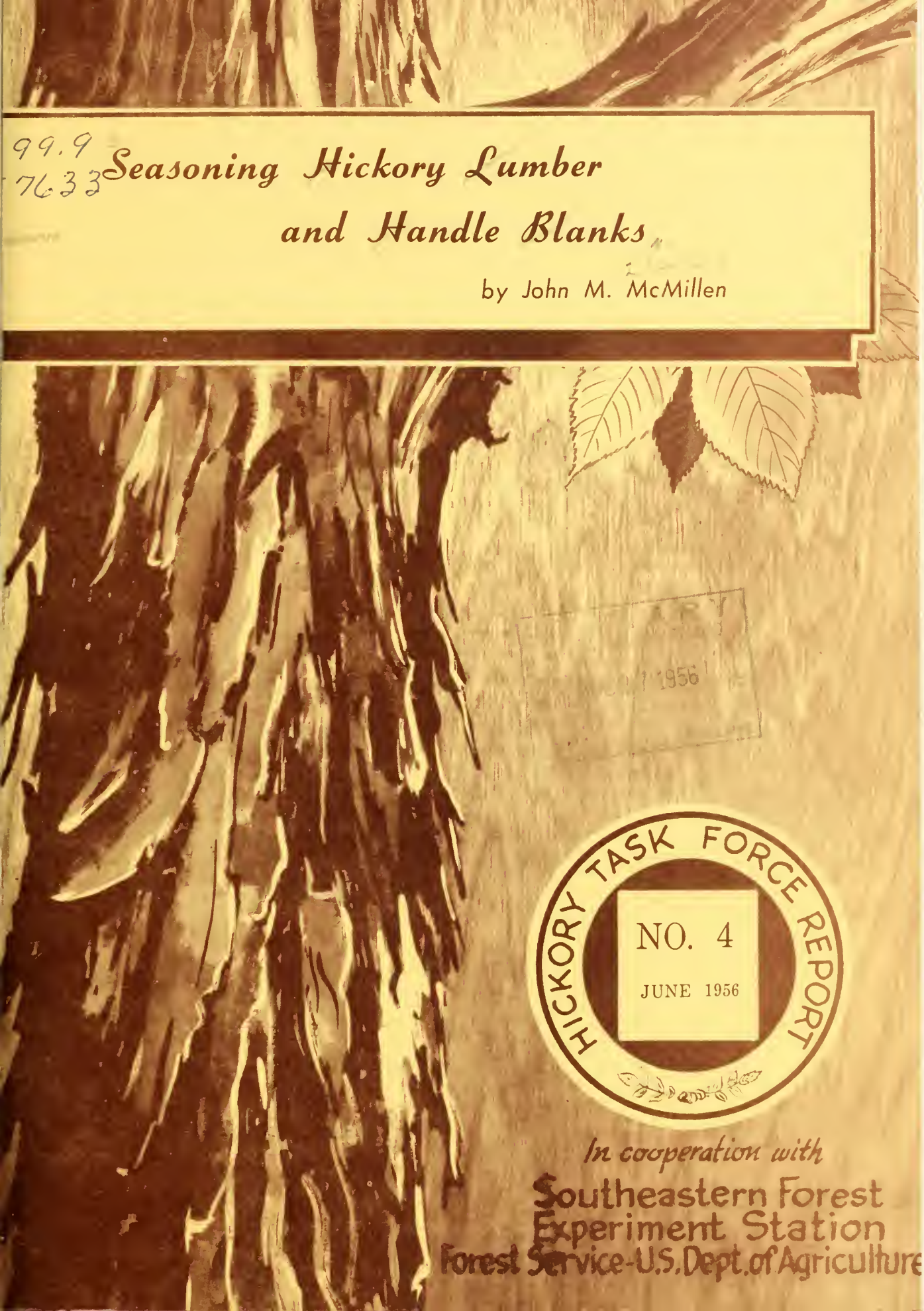
Seasoning Hickory Lumber and Handle Blanks

by John M. McMillen



1956

HICKORY TASK FORCE REPORT

NO. 4

JUNE 1956

In cooperation with

Southeastern Forest Experiment Station
Forest Service-U.S. Dept. of Agriculture

FOREWORD

Hickory (Carya spp.) has earned the reputation of being one of the world's toughest woods. In shock resistance it has no equal. The reputation earned by hickory is based on the performance of high quality material in products requiring a high degree of strength and toughness.

Today, a limited quantity of high-grade hickory is available and its value and scarcity are well recognized by the wood-using industries. There is, however, a large volume of low-grade hickory that was bypassed when loggers cut our hardwood forests, and many land managers are troubled by the increasing amount of growing space occupied by it. Although this low-grade hickory does not possess the quality or properties required in many products, it is a potentially valuable wood for many uses.

A conference of federal, state, university, and industrial representatives was held in Clemson, S. C., in April 1953, and the Hickory Task Force was organized to promote the utilization of hickory. Accomplishment of this objective will be reached through research and publication of known information.

The Southeastern Forest Experiment Station has assumed the responsibility to edit, publish, and distribute reports containing information which will be developed under this program.

Full acknowledgment is due the many cooperating agencies and individuals who are making the project possible. Subject Matter Committee Chairmen are:

John Drow, Forest Products Laboratory, Madison, Wis., Growth and Properties of Hickory.
Roger Anderson, Duke University, Durham, N. C., Enemies of Hickory.
Roy M. Carter, N. C. State College, Raleigh, N. C., Manufacturing and Seasoning of Hickory.
John W. Lehman, Tennessee Valley Authority, Norris, Tenn., Products from Hickory.
Lenthall Wyman, N. C. State College, Raleigh, N. C., Hickory for Fuel.
C. E. Libby, N. C. State College, Raleigh, N. C., Hickory for Fiber.
Monie S. Hudson, Spartanburg, S. C., Treating Hickory.
Richard D. Lane, Central States Forest Experiment Station, Carbondale, Ill., Marketing of Hickory.

Walton R. Smith, Chairman
Hickory Task Force

See the inside back cover for a list of hickory reports planned.

SEASONING HICKORY LUMBER AND HANDLE BLANKS [1]

by

John M. McMillen, [2] Technologist
Forest Products Laboratory, [3] Forest Service
U. S. Department of Agriculture

CONTENTS

	Page		Page
Summary	1	Handle blanks and special items	17
Introduction	2	Production considerations	17
Care of logs and bolts	4	Air drying	18
Lumber	5	Kiln drying	23
Air drying	5	Control of pinking	30
Kiln drying	8	Dry storage	33
Dry storage	17	Toughness and drying procedures	34
		Literature cited	35

SUMMARY

This paper describes proper air-drying and kiln-drying procedures for hickory lumber, handle stock, and other items based on extensive research at the U. S. Forest Products Laboratory. Some 90 separate kiln runs were made. Pignut, mockernut, shagbark, and sand hickory were the principal species studied, but water hickory (bitter pecan) also was included. The material came from South Carolina, Kentucky, and Mississippi. The report describes the control of pinking in handle stock and the effect of the kiln schedules on toughness. Information obtained from pilot testing the handle-blank kiln schedules at Mississippi State College and from visits of the author and O. W. Torgeson to handle-blank mills and handle factories in Tennessee and Mississippi is also included.

1/ Acknowledgement is made to the Poinsett Lumber and Manufacturing Co., Pickens, S. C., the W. M. Ritter Lumber Co., Pineville, Ky., and Mississippi State College, State College, Miss., for cooperation in supplying test material.

2/ Experimental work was carried out under guidance and direction of O. W. Torgeson and with the assistance of the Southeastern, Southern, and Central States Forest Experiment Stations in deciding on and supplying proper test material.

3/ Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

INTRODUCTION

Proper seasoning is vital for a great many of hickory's uses. It is one of the denser hardwoods and requires more careful drying than pine and yellow-poplar. Since stresses from the living tree make it subject to splitting and shake, extra care is needed from the time it is felled to the storage period. When proper procedures are followed, hickory can be precisely dried to satisfactory moisture content and machined without excessive difficulty.

Since much of the better quality hickory is used for striking-tool handles, skis, and loom picker sticks, a large portion of this report is devoted to seasoning methods for such items. Large quantities of hickory are available, however, for flooring, furniture, and similar products. Since greater expansion is likely in the use of hickory as lumber than as special stock, the economical seasoning of lumber is described first. A brief discussion of the care of logs and bolts prior to sawing precedes the two main sections. Control of the stain called pinking and the effect of kiln temperatures on toughness are discussed in the handle-blank portion. Equalizing and conditioning to prevent overdrying, restore surface moisture, and relieve drying stresses are discussed under lumber seasoning. Proper storage of dried stock is discussed separately under each of the main seasoning headings.

The details on experimental material used are too extensive to be included in this paper. Figure 1, however, shows the ends of some of the logs. The first research was done on second-growth pignut hickory from Mississippi. This material, although of rapid growth highly suitable for handle stock, was the easiest to dry without seasoning defects. Later research was done on forest-grown pignut, mockernut, and sand hickory from South Carolina and old-growth shagbark hickory from Kentucky. Limited research was done on water hickory (bitter pecan) from Mississippi. There was no appreciable difference in drying characteristics among the major species of hickory tested. A small amount of material from each species was especially prone to seasoning defects. Bitter pecan sapwood and sand hickory dried easier and faster than the other material, but bitter pecan heartwood was especially slow and difficult to dry.

The experimental kiln runs were made in the Laboratory's small cross-circulation kilns with an air velocity through the load of about 300 to 500 feet per minute. The experimental results on the lumber schedules were supported by pilot test or check runs of about 300 board-feet for each thickness. The kiln schedules developed experimentally for small handle blanks of Mississippi-grown hickory were pilot tested (1) [4] on smooth, slightly scaly, and shaggy bark hickory obtained at Columbus, Mississippi.

The drying procedures and kiln schedules given should be generally suitable for all hickory lumber and dimension stock. In some cases, easily dried second-growth hickory can be dried by more severe schedules.

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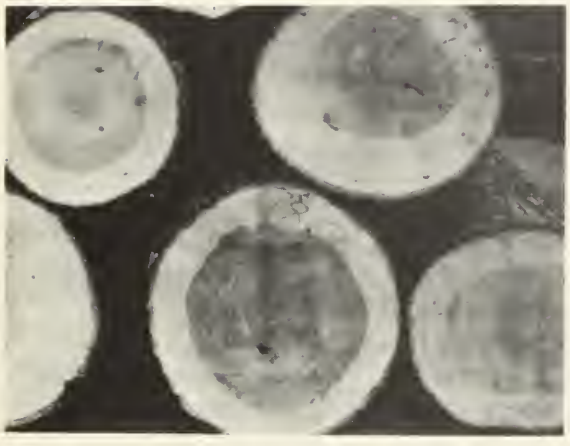
[4] Underlined numbers in parentheses refer to literature cited at the end of this paper.

A



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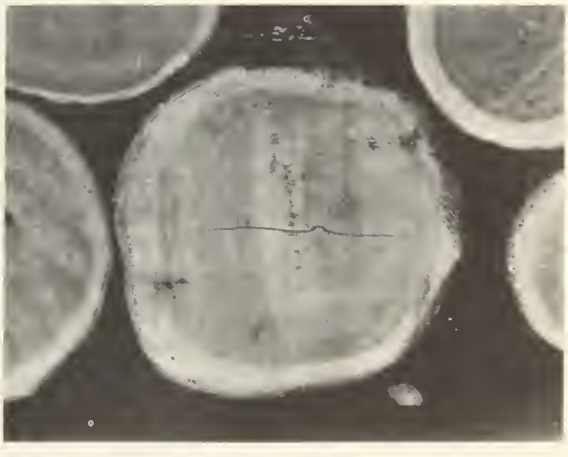

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Figure 1.--Ends of hickory logs used in seasoning studies at U. S. Forest Products Laboratory. A, Second-growth pignut hickory from Mississippi. B, C, D, Forest-grown pignut, sand, and mockernut hickory from South Carolina. E, Old-growth shagbark hickory from Kentucky.

CARE OF LOGS AND BOLTS

Freshly cut hickory logs and bolts are subject to both short-term and long-term hazards. Stresses in the living tree, described in another paper of this series, may cause severe splitting at the time of felling and bucking or soon afterwards. No satisfactory method of preventing these splits is known, but if the stresses could be allowed to relieve themselves gradually, the damage would be kept at a minimum. Keeping the logs in the shade, keeping them wet, and using end coatings would help keep drying stresses from adding to the tree stresses, and this should reduce splitting.

Long-term hazards include end checking, fungus stain and decay, and insect attack. Damage is most rapid in logs cut between June and October, when fungi and wood- and bark-boring beetles are most active. In the Gulf States, stain and decay are not stopped completely even in the wintertime. The beetles contribute to fungus damage by carrying spores through the bark into the logs. Stain and decay also penetrate the ends of logs rapidly.

The following suggestions are given for protecting logs and bolts from damage:

1. Keep logs in shade and wet them down or store them under water if possible.

2. Saw logs into lumber or dimension stock within a week or two of felling.

3. Spray the ends and sides thoroughly with a combined fungicide-insecticide if logs must be decked up for longer than 2 weeks. Make up a toxic solution of 2.5 percent pentachlorophenol and 0.5 percent gamma isomer of benzene hexachloride in No. 2 fuel oil. Commercial benzene hexachloride is only partly made up of this isomer, so enough must be used to bring the gamma portion up to 0.5 percent. To prevent stain penetration, spraying must be done within 24 hours of cutting. Two to three gallons of solution are needed for a thousand board-feet, log scale.[5/]

4. Use an end coating to prevent end checks. The insect and fungus spray will fail if the end checks expose untreated wood to attack. In some cases, a spray of wax emulsion may be sufficient, while in others, a heavier coating may be required.[6/]

5/ Chemicals obtainable from Chapman Chemical Co., Memphis, Tenn.; E. I. duPont de Nemours and Co., Wilmington, Del.; and Wood-Treating Chemicals Co., St. Louis, Mo. Other sources and details of treatment are given in Literature Cited (2) and (8).

6/ Wax emulsion coating is available from Socony Vacuum Oil Co., and R. T. Vanderbilt Co., both of New York City, and the heavier type can be obtained from Flintkote Co., Chicago Heights, Ill., and Chapman Chemical Co., Memphis, Tenn. Other sources are presented in Literature Cited (14).

LUMBER

Proper seasoning procedures should make hickory lumber a more salable product. Hickory lumber can be successfully kiln dried from both the green and the air-dried conditions. The best control of drying defects is obtained by kiln drying as soon as possible after milling. Like other hardwoods, however, the bulk of the lumber probably will be air dried first. The kiln schedules described in this report are of the accelerated type and should save considerable time in drying. The lumber should come out uniform in moisture content, not overdried. Machining operations should be less difficult because of the recommended conditioning treatments.

Air Drying

When hickory is air seasoned, certain piling methods are important to insure uniform and fairly rapid drying without excessive seasoning defects. The essentials of good piling practice for hand piling on a seasoning yard are shown in figure 2. When fork-lift trucks and unit-package handling are used, the usual practice is to pile the packages horizontally or on the level, although they can be sloped also. The piles should not be crowded together. They should be tightly roofed. A 12- to 18-inch air space should be left under each pile. Figure 3 shows a unit-package pile in which slope has been obtained by building a slight pitch into each unit and then piling the units with a tilting-fork truck. Thick hickory lumber probably should be air dried in a shed. General information on yard layout and other phases of air drying are given in another report (6).

Hickory sapwood air dried in the summer should be dipped to prevent blue stain (11). Chemicals serving to prevent insect attack (2) should be included in the dip when heavy infestations of powder-post beetles are known to be present and the air-drying period is of undecided length.

Information on air-drying time for hickory lumber was not obtained in the U. S. Forest Products Laboratory studies. An air-seasoning study on 1-inch beech lumber in Pennsylvania, however, showed that it air dried from 55 to 20 percent moisture content in $2\frac{1}{2}$ months or less if piled during the first $9\frac{1}{2}$ months of the year. Beech lumber piled after October 15 did not dry to 20 percent until March. Somewhat the same drying times could be expected for 1-inch hickory. Longer times, of course, would be needed to dry thicker lumber to 20 percent moisture content.

Hickory lumber can be kiln dried from the green condition or from any stage of partial air drying. The initial kiln conditions must be chosen on the basis of actual moisture content of the stock as it goes into the kiln. One cannot safely assume that air seasoning the lumber for 90 days or any other set period of time will completely remove danger of honeycombing.

Although prolonged air drying will bring hickory lumber down to 12 to 15 percent moisture content, it must be dried further for interior use. Small amounts can be dried in a heated room (7), but kiln drying is required for commercial uses.

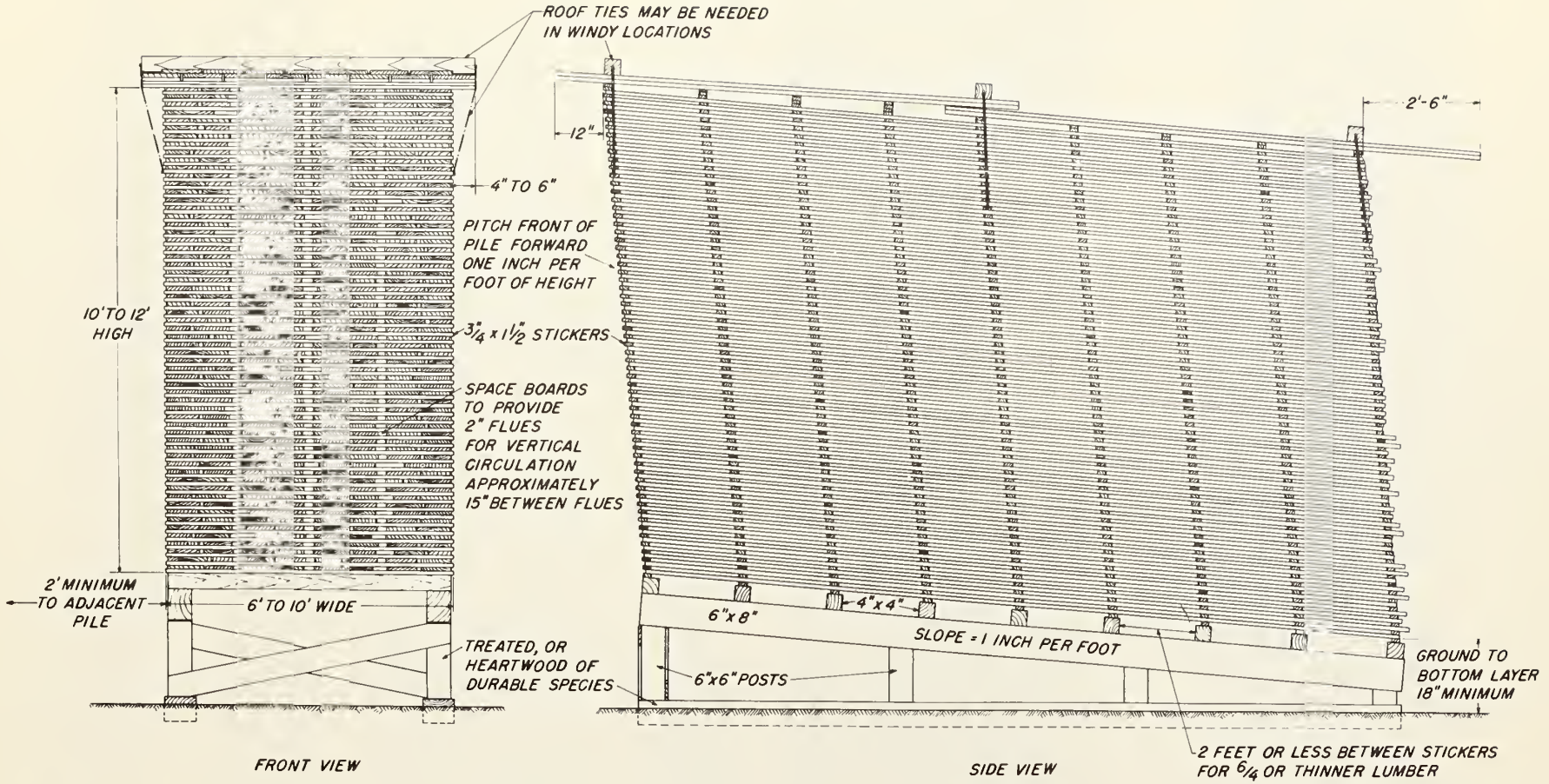

ROOF TIES MAY BE NEEDED IN WINDY LOCATIONS
12"
2'-6"
4" TO 6"
PITCH FRONT OF PILE FORWARD ONE INCH PER FOOT OF HEIGHT
10' TO 12' HIGH
3/4" x 1 1/2" STICKERS
SPACE BOARDS TO PROVIDE 2" FLUES FOR VERTICAL CIRCULATION APPROXIMATELY 15" BETWEEN FLUES
2' MINIMUM TO ADJACENT PILE
6' TO 10' WIDE
TREATED, OR HEARTWOOD OF DURABLE SPECIES
6"x8"
4"x4"
SLOPE = 1 INCH PER FOOT
6"x6" POSTS
GROUND TO BOTTOM LAYER 18" MINIMUM
2 FEET OR LESS BETWEEN STICKERS FOR 6/4 OR THINNER LUMBER
FRONT VIEW
SIDE VIEW

Figure 2.--Good hand piling methods for hickory lumber.

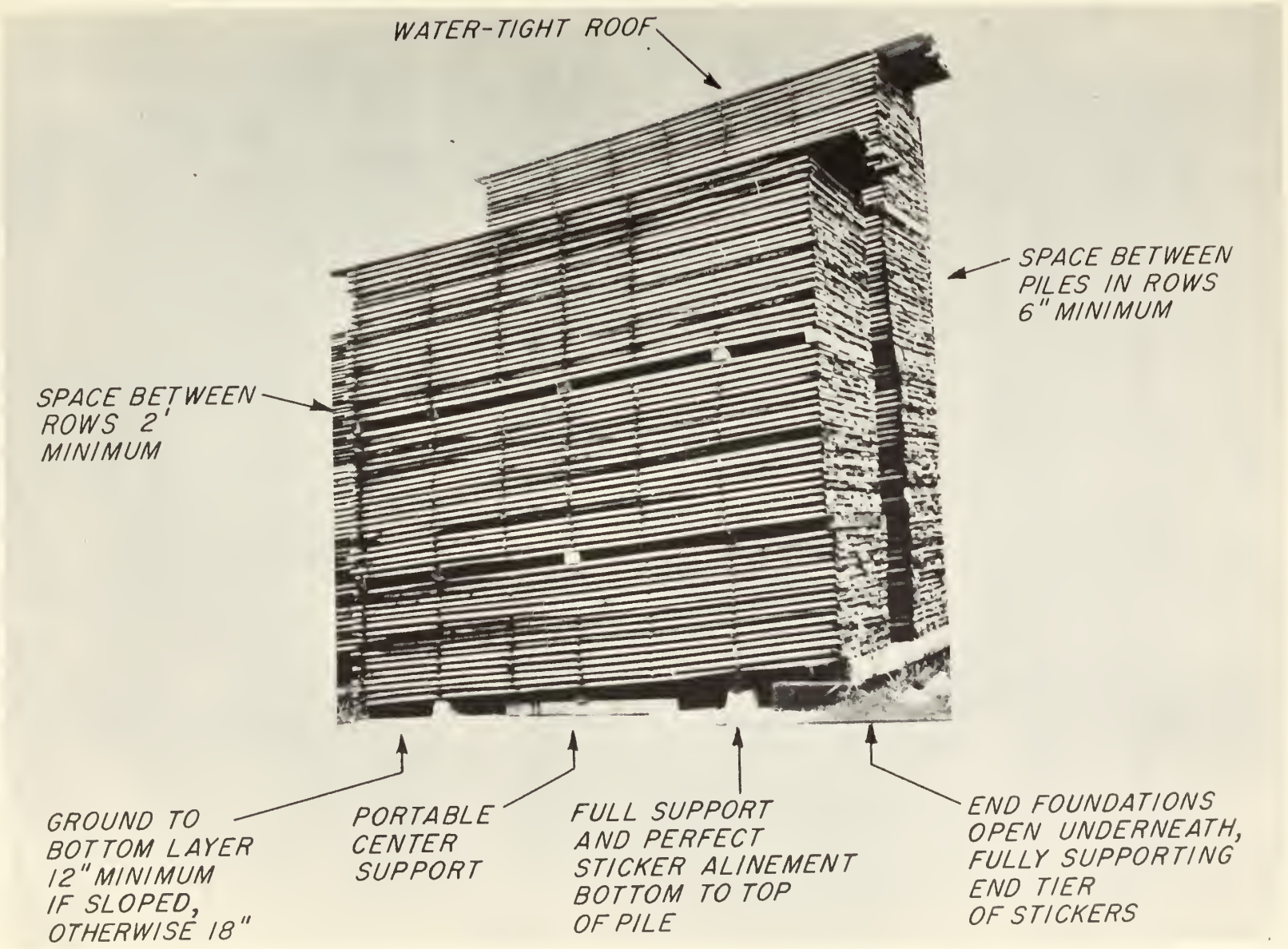

WATER-TIGHT ROOF
SPACE BETWEEN PILES IN ROWS 6" MINIMUM
SPACE BETWEEN ROWS 2' MINIMUM
GROUND TO BOTTOM LAYER 12" MINIMUM IF SLOPED, OTHERWISE 18"
PORTABLE CENTER SUPPORT
FULL SUPPORT AND PERFECT STICKER ALINEMENT BOTTOM TO TOP OF PILE
END FOUNDATIONS OPEN UNDERNEATH, FULLY SUPPORTING END TIER OF STICKERS

Figure 3.--Good package-piling methods for hickory lumber.

Kiln Drying

Proper kiln drying of hickory requires good equipment and good operating procedures. The essentials of a good kiln are adequate air circulation with means of control to insure uniform temperature and relative humidity throughout the kiln. Such conditions are best achieved in a modern forced-air circulation kiln designed by a regular dry kiln manufacturer or engineer (13). The stock must be piled to make good air circulation possible and to hold the lumber flat. Also, the kiln operator needs to know the exact moisture content of the lumber at all stages of drying.

Stacking and Green Storage

The essentials of stacking lumber for kiln drying are similar to those for stacking lumber for air drying. The lumber is piled flat, of course. Four types of stacking are common: hand stacking on kiln trucks, automatic stacking on trucks, unit-package stacking on kiln trucks, and unit-package stacking directly in the kiln. In all cases, a solid foundation under each tier of stickers and stickers vertically alined are essential. Where hand stacking is used, sticker guides help bring about proper alinement. A sticker spacing of 2 feet should be satisfactory for 4/4 stock. When unit packages are piled side by side either on kiln trucks or in the kiln, a 6-inch space should be left between the packages; otherwise air circulation may be hindered by improper alinement of the sticker spaces.

At several furniture plants, the entire green-storage area for lumber waiting to go into the kiln has been roofed over. This has proved very worthwhile and should be especially so for plants using hickory.

Kiln Samples

In modern kiln drying of hardwoods, the use of sample boards to show the progress of the drying enables the kiln operator to use accelerated schedules without danger of serious checking or honeycombing. Most of the samples should be selected from the slowest drying stock in the load, which is usually heartwood material. A sample width of about 8 inches is satisfactory. One or two samples should be selected from the fastest drying stock, usually narrow sapwood boards. Ten to twelve samples should be used for each charge until the operator becomes familiar with the drying of hickory in his kiln. Details of sample procedure are discussed in another report (12). Some of these details are discussed in the section, "Drying Samples," in the handle-blank portion of this report. Since the samples for lumber are to represent the drying of long boards, their ends should be coated (3).

Kiln Schedules

The kiln schedules developed through intensive research for 4/4, 6/4, and 8/4 hickory lumber are shown in table 1.

Table 1.--Kiln schedules for hickory lumber

Moisture content	Temperature			Relative humidity	Equilibrium moisture content
	Dry bulb	Wet bulb	Wet-bulb depression		
Percent	°F.	°F.	°F.	Percent	Percent
4/4 LUMBER					
Green to 50	130	125	5	86	16.0
50 to 40	130	123	7	81	14.0
40 to 30	130	114	16	60	9.4
30 to 25	150	112	38	30	4.5
25 to 20	150	100	50	18	2.9
20 to 6	180	130	50	26	3.3
Equalize	180	144	36	40	4.8
Condition (24 hours)	180	169	11	77	10.6
6/4 LUMBER					
Green to 50	120	115	5	85	16.2
50 to 40	120	113	7	80	14.1
40 to 35	125	114	11	70	11.5
35 to 30	130	97	33	30	5.0
30 to 20	140	104	36	30	4.8
20 to 6	180	130	50	26	3.3
Equalize	180	144	36	40	4.8
Condition (30 hours)	180	169	11	77	10.6
8/4 LUMBER					
Green to 50	120	117	3	91	19.0
50 to 40	120	116	4	88	17.4
40 to 35	120	113	7	80	14.1
35 to 30	125	114	11	70	11.5
30 to 25	130	97	33	30	5.0
25 to 20	140	90	50	14	2.6
20 to 15	150	100	50	18	2.9
15 to 6	180	130	50	26	3.3
Equalize	180	144	36	40	4.8
Condition (48 hours)	180	169	11	77	10.6

Kiln changes should be made on the basis of the average moisture content of the wetter half of the total number of kiln samples. Even though the moisture content of the stock at the time it goes into the kiln may be near or below 50 percent, the kiln should be run 16 to 24 hours on the first step of the appropriate schedule. Then the kiln should be shifted to step 2 of the schedule and run on the moisture content basis thereafter.

The equalizing and conditioning treatments are shown for a final average moisture content of 7 percent. Suggestions for equalizing and conditioning to other final moisture content values are given in a later section of this report.

The kiln schedules given in the table above are the final results of a number of experiments with a wide variety of hickory material and include some minor modifications consistent with the initial conditions prescribed for hickory in the U. S. Forest Products Laboratory's general report on kiln schedules (10). As with any other kiln schedules, they are considered only as guides for a kiln operator to use in working out schedules more perfectly fitting his own type of material and kiln. Although the particular temperatures and relative humidities shown above for the initial conditions were not actually tried in the research, enough work was done with temperatures in that range to indicate that they should be safe in kilns with uniform drying conditions throughout the kiln. In kilns which may have hot zones above the temperature at the instrument bulbs, the lower initial temperature conditions shown in figures 4, 5, and 6 should be used. Details in these figures will be of considerable assistance to the kiln operator and plant manager unfamiliar with hickory.

Experimental Basis for Schedules

The actual schedule and drying curve of the final experimental run with flat-grain 4/4 lumber are shown in figure 4. Drying time, including equalization and conditioning, was 12 days. The stock dried without any surface checking, and the average end-check penetration was 1.5 inches. The maximum end-check penetration was about 3 inches. This drying time was obtained when drying a small lot of lumber in an experimental kiln. The drying curve should not be used as a time schedule, because longer time on each step can be expected in commercial kilns. In a pilot test run with a slightly milder schedule, the total time was 15 days. The stock had only very mild end checking.

The actual schedule and the drying curve for the experimental run with flat-grain 6/4 stock 8 inches wide are shown in figure 5. Drying time was 15 days including equalization and conditioning. Ski stock, flat-grain but $4\frac{1}{2}$ inches wide, took 2 days less. The ski stock and the other flat-grain stock was mostly sapwood, but some heartwood was included. Edge-grain stock about 5 to 7 inches wide and including considerable heartwood took 24 days.

There was only minor surface checking, which started from defects or end checks. Average end-check penetration was about 2.25 inches in the 8-inch-wide, flat-grain stock but 1.5 inches or less in the other 6/4 items. Maximum end-check penetration was about 3 inches. The few end checks

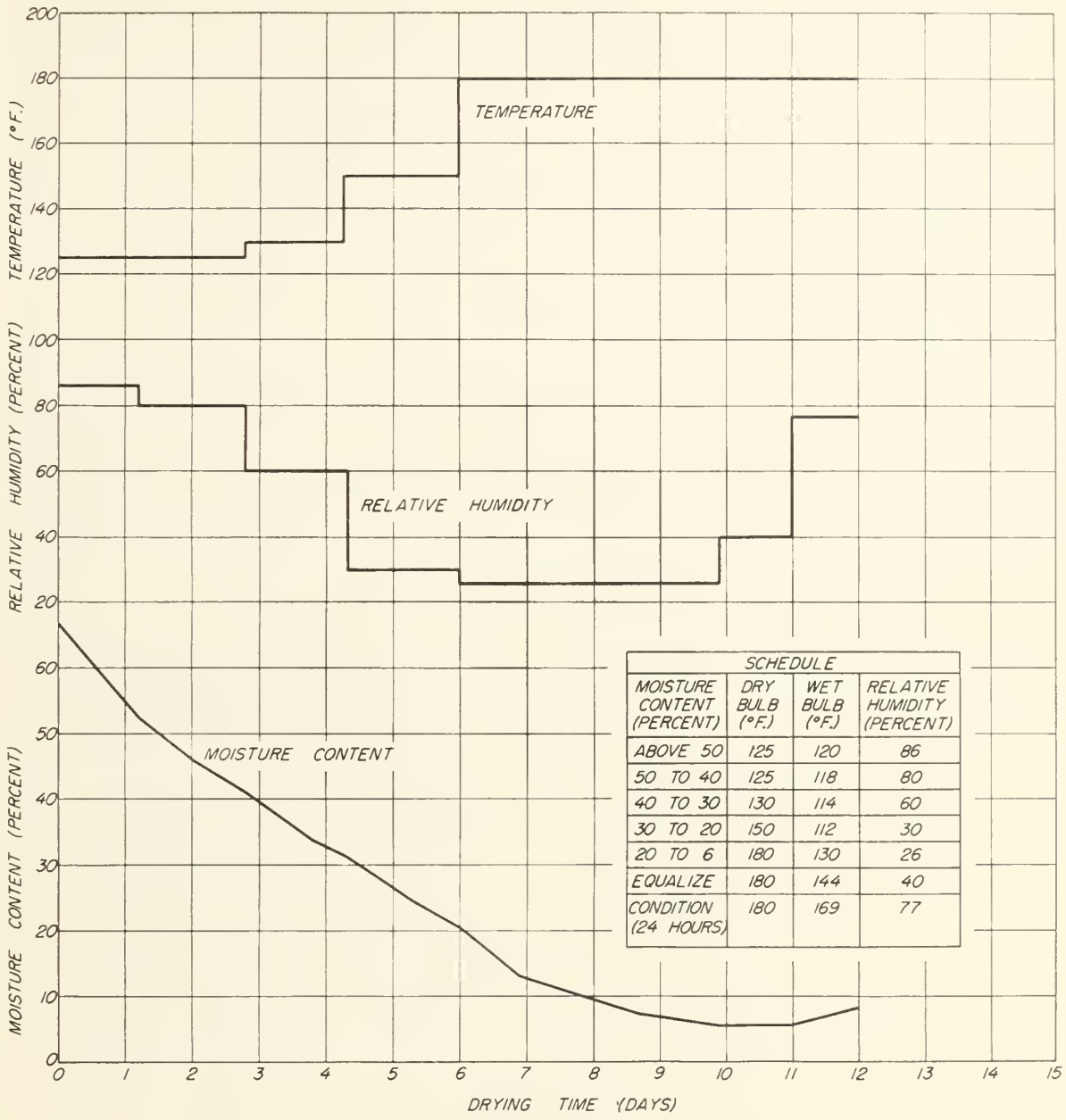

TEMPERATURE
RELATIVE HUMIDITY
MOISTURE CONTENT
RELATIVE HUMIDITY (PERCENT) TEMPERATURE (°F.)
MOISTURE CONTENT (PERCENT)
DRYING TIME (DAYS)
SCHEDULE
MOISTURE CONTENT (PERCENT) | DRY BULB (°F.) | WET BULB (°F.) | RELATIVE HUMIDITY (PERCENT)
ABOVE 50 | 125 | 120 | 86
50 TO 40 | 125 | 118 | 80
40 TO 30 | 130 | 114 | 60
30 TO 20 | 150 | 112 | 30
20 TO 6 | 180 | 130 | 26
EQUALIZE | 180 | 144 | 40
CONDITION (24 HOURS) | 180 | 169 | 77

Figure 4.--Kiln schedule and drying curve for 4/4 hickory lumber.

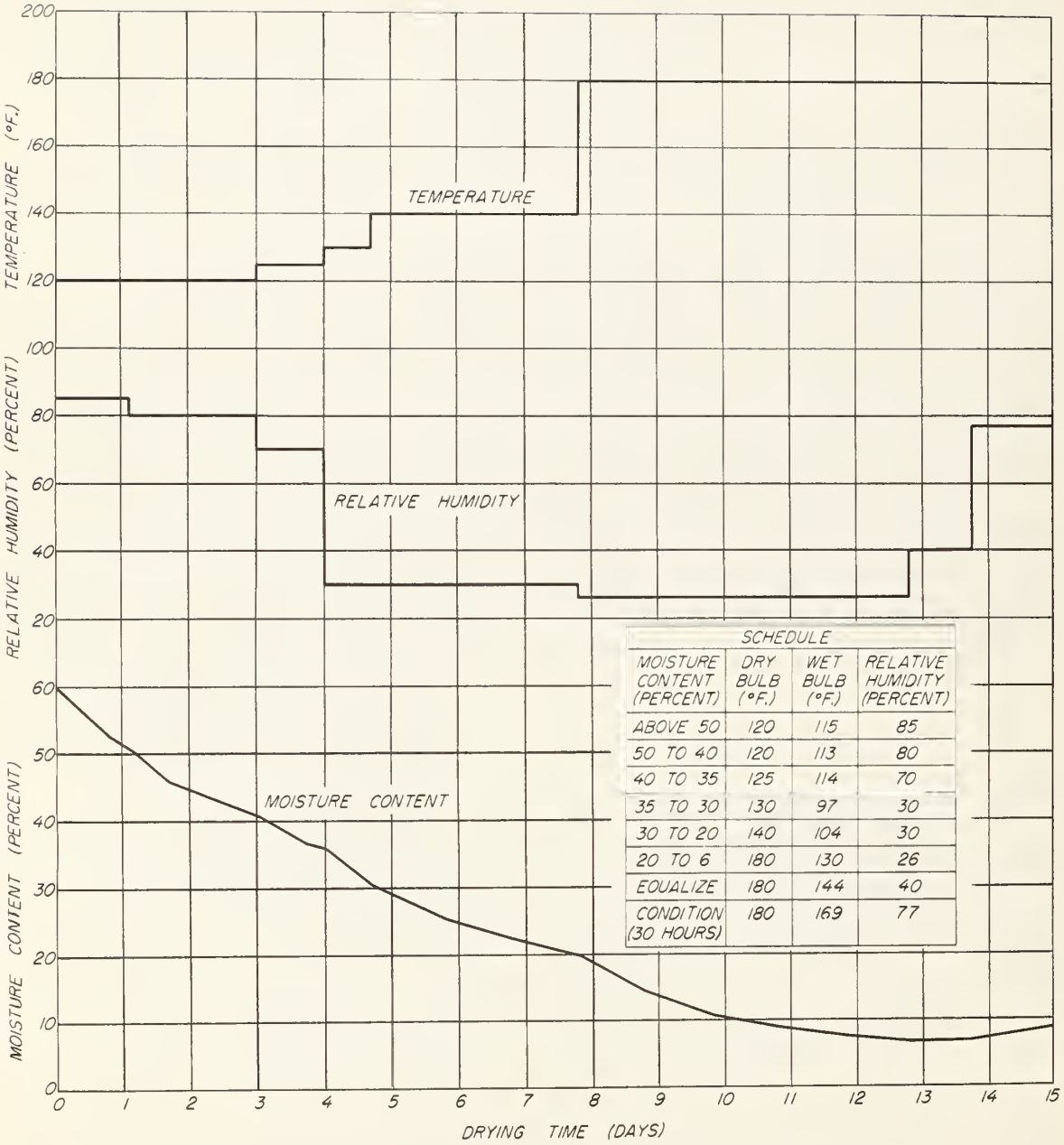
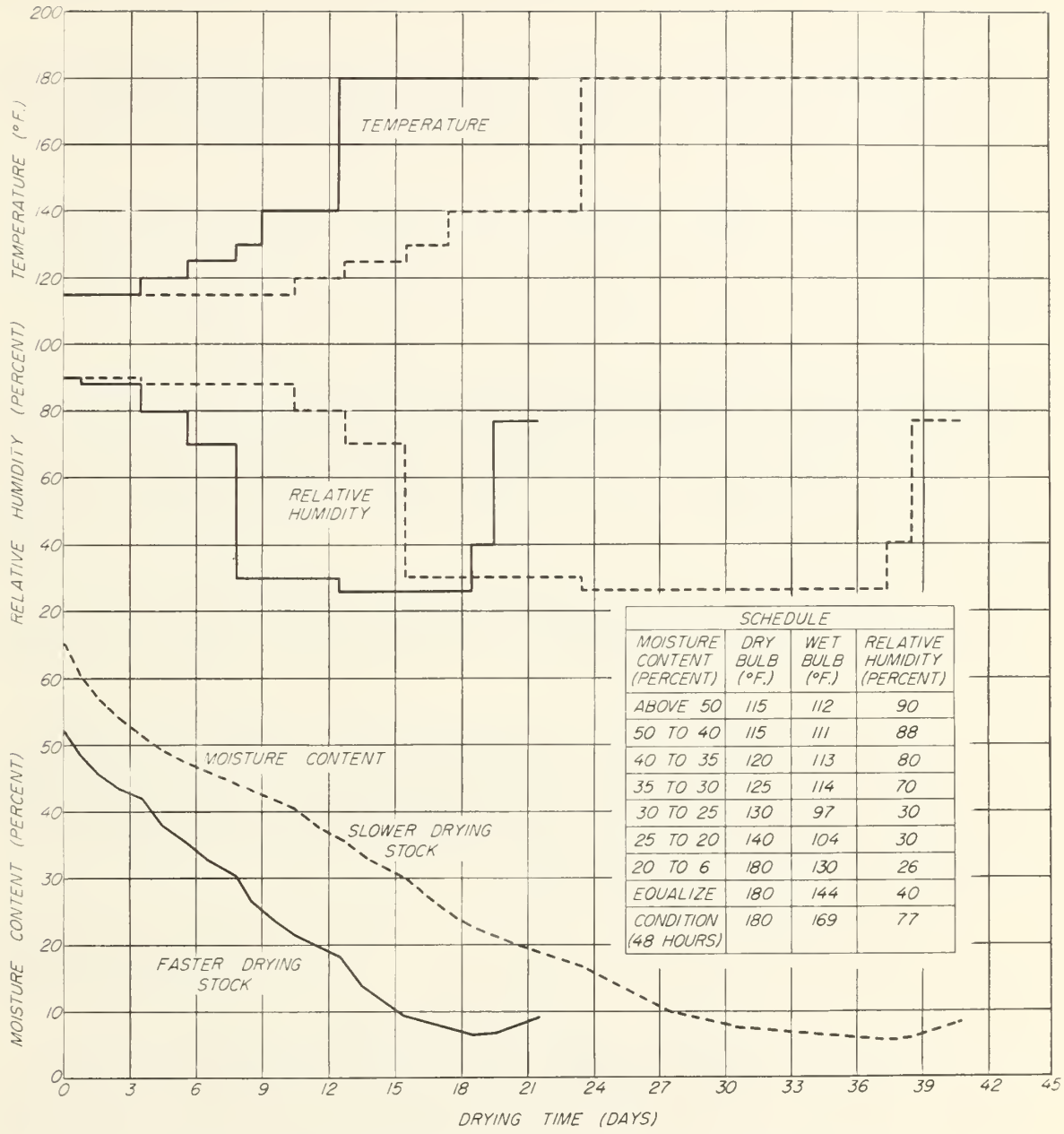

TEMPERATURE (°F.)
RELATIVE HUMIDITY (PERCENT)
MOISTURE CONTENT (PERCENT)
TEMPERATURE
RELATIVE HUMIDITY
MOISTURE CONTENT
DRYING TIME (DAYS)
SCHEDULE
MOISTURE CONTENT (PERCENT) | DRY BULB (°F.) | WET BULB (°F.) | RELATIVE HUMIDITY (PERCENT)
ABOVE 50 | 120 | 115 | 85
50 TO 40 | 120 | 113 | 80
40 TO 35 | 125 | 114 | 70
35 TO 30 | 130 | 97 | 30
30 TO 20 | 140 | 104 | 30
20 TO 6 | 180 | 130 | 26
EQUALIZE | 180 | 144 | 40
CONDITION (30 HOURS) | 180 | 169 | 77

Figure 5.--Kiln schedule and drying curve for 6/4 hickory lumber.


TEMPERATURE
RELATIVE HUMIDITY
MOISTURE CONTENT
SLOWER DRYING STOCK
FASTER DRYING STOCK
RELATIVE HUMIDITY (PERCENT) TEMPERATURE (°F.)
MOISTURE CONTENT (PERCENT)
DRYING TIME (DAYS)
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45
0 10 20 30 40 50 60 80 100 120 140 160 180 200

SCHEDULE

MOISTURE CONTENT (PERCENT)	DRY BULB (°F.)	WET BULB (°F.)	RELATIVE HUMIDITY (PERCENT)
ABOVE 50	115	112	90
50 TO 40	115	111	88
40 TO 35	120	113	80
35 TO 30	125	114	70
30 TO 25	130	97	30
25 TO 20	140	104	30
20 TO 6	180	130	26
EQUALIZE	180	144	40
CONDITION (48 HOURS)	180	169	77

Figure 6.--Kiln schedule and drying curves for 8/4 hickory lumber.

that opened up as honeycomb checks did not extend more than 3 inches back from the ends. There was no other honeycombing and no collapse or bad distortion.

In a pilot test run made with flat-grain stock on a slightly milder schedule, total drying time was 21 days. Results were satisfactory. End checking was about the same as in the experimental runs, and no surface checking occurred.

Segregation of edge-grain 6/4 stock from flat-grain 6/4 stock appears to be desirable from the standpoint of drying time. If necessary, the edge-grain stock can be partially air seasoned before kiln drying, or edge-grain 6/4 stock could be dried in the same kiln as flat-grain 8/4 sapwood.

The actual schedule and drying curves for two different classes of 8/4 lumber are shown in figure 6. At the start of the experiment, the material was divided into two groups according to moisture content. In the wetter group, the average moisture content of the 5 wettest samples was 65.2 percent, while in the other group the moisture content of the 5 wettest samples averaged 52.1 percent. The same schedule was used in drying the two groups, but a longer time was required in each step for wetter and slower drying material. Drying time, including equalization and conditioning, was 22 days for the faster drying stock and 41 days for the slower drying stock. The faster drying stock was largely sapwood with some heartwood, while the slower drying stock was mostly heartwood.

Although the specimens in this experiment were about equally divided between the two moisture content groups, most of the material from the logs in the entire hickory study was of the faster drying type. If the proportion of slow drying material is small, it should be segregated and air dried, or cut into thinner stock; the slower drying rate does not seem to be of as much practical consequence for thin stock.

Surface checking occurred in only 1 of the 8/4 specimens, and this was minor checking connected with a natural defect. Average end-check penetration was less than 1.5 inches. Maximum penetration was about 3 inches. There was no honeycombing. The pilot test with this size of stock was made prior to the experimental kiln runs. Under a schedule similar to the 6/4 schedule, surface checking and deep end checking occurred in many of the boards. Collapse and honeycombing occurred in the more refractory material. As a result of this pilot test, milder conditions were set up for the final schedule.

Modification of Schedules for Maximum Strength

Hickory has many uses for which maximum strength is of primary importance. Although toughness tests on handle stock dried by the schedules in this report generally indicate that a final high temperature of 180° F. does not decrease toughness, it has been the custom to avoid temperatures over 165° F. when ultimate strength is a big factor. Hence, the final high temperature step of each schedule can be operated at 165° F. with a 50° F. wet-bulb depression.

Modification of Schedules for Color Control

All the above schedules will cause pinking. Pinking is a pinkish to reddish-brown coloration of the sapwood caused by chemical changes in the sap normally present in the wood. The control of pinking in hickory handle stock is described later in this report. In brief, pinking can be prevented, except for a very small discoloration in the cores of a small percentage of the boards, by keeping the dry-bulb temperature down to 105° F. or below until the stock has dried to an average moisture content of 20 percent. From 20 to 12 percent moisture content, the temperature should not exceed 115° F. Below 12 percent, any kiln temperature can be used.

Modification of Schedules for Variation of Material

The schedules and the corresponding drying curves given in this report were obtained with the forest-grown pignut, mockernut, sand, and shagbark hickory from South Carolina and Kentucky. This material was considerably slower drying and required milder schedules than the second-growth pignut hickory from Mississippi. It is believed that these schedules can be used generally for any hickory.

If the end checking actually encountered is less than that reported here or if more can be tolerated, the schedules can be made more severe by slightly increasing the initial wet-bulb depression. The depression in the second step of the schedules could be increased correspondingly.

Some hickory may be very easy to dry. For example, the 4/4 stock from Mississippi dried satisfactorily with an initial dry-bulb temperature of 130° F. and a wet-bulb depression of 20° F. Initial conditions were maintained until the lumber reached 30 percent moisture content. The kiln then was changed to 150° F. and 38° F. wet-bulb depression. At 20 percent moisture content, conditions were changed to 180° F. and 45° F. wet-bulb depression. Drying time was only 6 days, including 1 day of conditioning. Most of the material in this run was sapwood, but one specimen contained some heartwood.

On the other hand, a small percentage of the specimen material from South Carolina and Kentucky used in the handle-blank study appeared to be especially prone to surface checking and deep end checking. This type of material was not included in the experiments on the drying of hickory lumber, but it is not believed to comprise a very large percentage of normal hickory lumber. If any commercial lot of hickory lumber should give evidence of containing a large percentage of boards prone to checking, the schedules given in this report should be modified by reducing the initial or early wet-bulb depressions, or reducing the dry-bulb temperatures, or both.

The older heartwood material from the old-growth shagbark hickory appeared to be slower drying and more susceptible to honeycombing and collapse than the other hickory tested. If any of this type of material is included in a charge, the humidity schedules that are given are satisfactory.

However, the kiln temperature should be kept at 130° F. or below until the stock is dried down to 20 percent moisture content, or down to 15 percent for 8/4 or thicker material.

Kiln Drying of Air-Dried Stock

Stock that has been air dried only a short time should be started on the first or second step of the appropriate schedule. Kiln conditions should be maintained for at least a day in each step until the average moisture content of the wetter samples coincides with the moisture content of the schedule. After that, the moisture content of these samples should govern kiln changes. Partially air-dried 4/4 and 6/4 stock between 30 and 20 percent moisture content and 8/4 stock between 30 and 15 percent should be started at 130° to 140° F. with a 10° F. wet-bulb depression. Air-dried 4/4 and 6/4 stock below 20 percent and 8/4 stock below 15 percent can be started at 140° to 150° F. with a 20° F. wet-bulb depression. After one day at these conditions, the kiln can be changed to the conditions indicated for the proper step of the appropriate kiln schedule.

Equalization and Conditioning

Equalization of moisture content between boards and between shell and core of the individual boards is important for high-grade use of any hardwood. Relief of drying stresses (casehardening) is also important if the material is to be used for furniture. These procedures are especially important for hickory. When hickory has been dried down to a low average moisture content without conditioning, the surface is likely to be so hard that machining is very difficult. To avoid this difficulty, shell moisture content is brought up to core moisture content during the conditioning operation. Limited machining tests have shown that hickory at 6 percent moisture content machines as easily and as well as hickory at 9 percent when proper equalizing and conditioning have been carried out.

The temperatures and relative humidities shown for the equalization and conditioning steps in the schedules are for a desired final average moisture content of 7 percent. If another final moisture content is desired, the following general suggestions are offered.

Near the end of the run, check the moisture content of the fastest drying sample. When the moisture content of this sample is 2 percent below the desired final average moisture content, change the kiln to the equalizing condition. This condition consists of a temperature the same as the final temperature of the regular schedule and a relative humidity adjusted to give an equilibrium moisture content 2 percent below the desired average. This treatment will arrest the drying of those boards that are already sufficiently dry. The kiln should be kept at this condition until the wettest sample is at the desired final average moisture content. Then the kiln should be changed to the stress-relieving conditioning treatment. This treatment consists of the final dry-bulb temperature and a relative humidity which will give an equilibrium moisture content 3.5 percent above the desired average. The stock should be held at these conditions for the number of hours shown in the schedules for the particular size of stock.

For example, when the desired final average moisture content is 9 instead of 7 percent, dry the driest sample to 7 percent. Then adjust humidity to 7 percent equilibrium moisture content. When the wettest sample is down to 9 percent, adjust humidity to 12 to 13 percent equilibrium moisture content. The 12 percent figure can be used with all-sapwood material. For heartwood material, use 13 percent equilibrium moisture content.

Hickory lumber that is going to be used at 10 to 12 percent moisture content or higher and is not going to be resawed or shaped may not require equalization and conditioning.

Dry Storage

Hickory lumber for furniture and other interior uses should be dried to a moisture content of 7 or 8 percent. When it is that dry, however, it will absorb moisture readily if exposed to high humidities in unprotected storage. Enclosed storage should be provided for such stock, with some provision for increasing the dry-bulb temperature slightly during periods of high humidity (5).

Lumber for exterior uses need not be held in enclosed storage. All dry hickory lumber must be guarded against insect attack if it is to be stored any length of time. A program for inspection and care to prevent losses is outlined under the section, "Dry Storage," in the handle-blank portion of this report. More details on control are given in another publication (9).

HANDLE BLANKS AND SPECIAL ITEMS

Handle blanks are the principal dimension items produced from hickory, but blanks for picker sticks, skis, ladder rungs, and golf club shafts are processed and dried in a similar manner. These items generally are produced from bolts or short logs, and a producer may sell all of them. He first produces as many long, high quality ski blanks as he can, then as many long handle blanks as possible, and then finishes up with the shorter items. Generally, the material is air dried before final kiln drying, since only a few pieces of the more valuable dimension items are accumulated at a time. Although the research upon which recommendations in this report are based was done on handle blanks, the procedures are suitable for all types of dimension stock and special items.

Production Considerations

The blanks should be protected from sun, rain, and wind during production. Sun and wind may cause end checking. Temperatures reached under direct exposure to the sun may be high enough to cause pinking. Thus, a handle-blank mill should be under a roof. Likewise, blanks split from bolts in the woods should be stacked under a roof, or the piles themselves should be roofed. Direct exposure of small piles to the sun in the summertime is not good practice.

Most handle blanks have a square or rectangular cross section, which makes them easier to stack and handle. This form, however, requires greater care in drying to prevent pinking of the interior, which will be exposed when final turning is done. Some handles are rough turned to an oversize dimension before kiln drying. Others are turned to final dimension and polished before final kiln drying. The latter is not good practice because there is then no satisfactory way to remove the small amount of crook or twist that occurs in some of the blanks.

Allowance should be made for shrinkage when the blanks are cut. Normal average radial shrinkage is 5.8 percent, and normal average tangential shrinkage is 9.1 percent when hickory is reduced to the kiln-dried condition. The experimental work indicated that shrinkage was affected by temperature. Least shrinkage occurred in drying at low temperature, while slightly greater shrinkage occurred at higher temperatures. The maximum shrinkage in thickness of small handle blanks was 7.0 percent, and the maximum shrinkage in width was 9.9 percent. The practice of supplying blanks in certain sizes when they are air dried has grown up in the industry. If a producer shifts to kiln drying, there will be greater shrinkage. This will necessitate either cutting the blanks slightly larger in the green condition or coming to some agreement with the purchaser as to the sizes he will take.

Small handle blanks 2 by 2 inches or less in cross section do not need to be end coated to control end checking. Larger blanks, however, should be end coated. Molten paraffin, which has been widely used, is very effective for air drying. The ends of the blanks are dipped quickly in the hot paraffin. For kiln drying at temperatures above 105° F., other coatings (14) should be used. Since end drying is of considerable importance in the drying of short-length blocks, the kiln schedules given in this report are designed to hold end checking to a reasonable amount while allowing drying through the ends.

Although bundling of blanks may simplify handling, it is not practical to dry the blanks in the bundles.

Lyctus beetles and other insects are a hazard with hickory, once it is dried. Most handle-blank producers are able to keep infestation out by keeping debris cleaned up and burned. When heavy infestations exist in nearby areas or when there is a possibility that the blanks may be left over a year in the seasoning piles, it may be wise to dip the green stock in a water emulsion of benzene hexachloride of the wettable type. The emulsion should give a concentration of at least 5 ounces of the gamma isomer portion of the hexachloride in 50 gallons of water. Details of preparation can be obtained from the chemical suppliers. 7/

Air Drying

Air drying is of major importance in the hickory handle and special item industry because it is the simplest way to produce stock with no pinking. Proper air-drying methods are fairly well known by established producers.

7/ See footnote 5.

Information on good air-drying practice has been included in this publication, however, to help solve such problems as may arise, to help trace possible causes of degrade, and to help producers of new products to avoid unnecessary losses.

Drying Shed

The essentials of proper air drying are protection of the stock from sun, rain, and wind and adequate air circulation to carry away moisture evaporated from the blanks. All air drying at permanent installations should be done in a shed. Essentials of a good shed are shown in figure 7. The floor should be made of preservative-treated hickory or oak with 1/2 to 3/4-inch spaces between the boards. The ground under the shed should be well drained. The stringers and joists should be heavy enough to support the weight of a small forklift truck loaded to capacity with green wood. Alleys and streets between the shed and other buildings must provide for cross ventilation as in a lumber seasoning yard.

When it is necessary to pile dimension stock in the open, the piles should be roofed as soon as completed. Their sides should be given protection against wind, sun, and driving rain. The pile foundations should hold the material at least 12 inches off the ground.

Piling

Handle blanks and other dimension stock should be piled by sizes and lengths. Essentials of proper piling practice are shown in figure 8. All the stock in each layer of the pile should have the same thickness. The spaces between rows should be lined up as much as possible to take advantage of horizontal air movement in the shed.

In making a pile, it would be desirable to leave pockets in which removable sample pieces for moisture content determination can be inserted. Since the stock in the lower third and near the center of the pile dries the slowest, the pocket should be located there. Each pile should be dated to help determine when the stock is ready for final kiln drying.

Degree of Drying and Drying Time

In the studies reported here, three groups of small handle blanks and two groups of large handle blanks were air dried. In addition, one group of small handle blanks was air dried in the pilot test at Mississippi State College (1). All these groups showed that pinking could be practically eliminated by air drying to a moisture content of 20 percent before kiln drying. If air drying is carried to this extent, no attention need be given to control of relative humidity during the first stages in kiln drying. If the stock is partially air dried to a moisture content above 20 percent, more care must be taken in kiln drying.

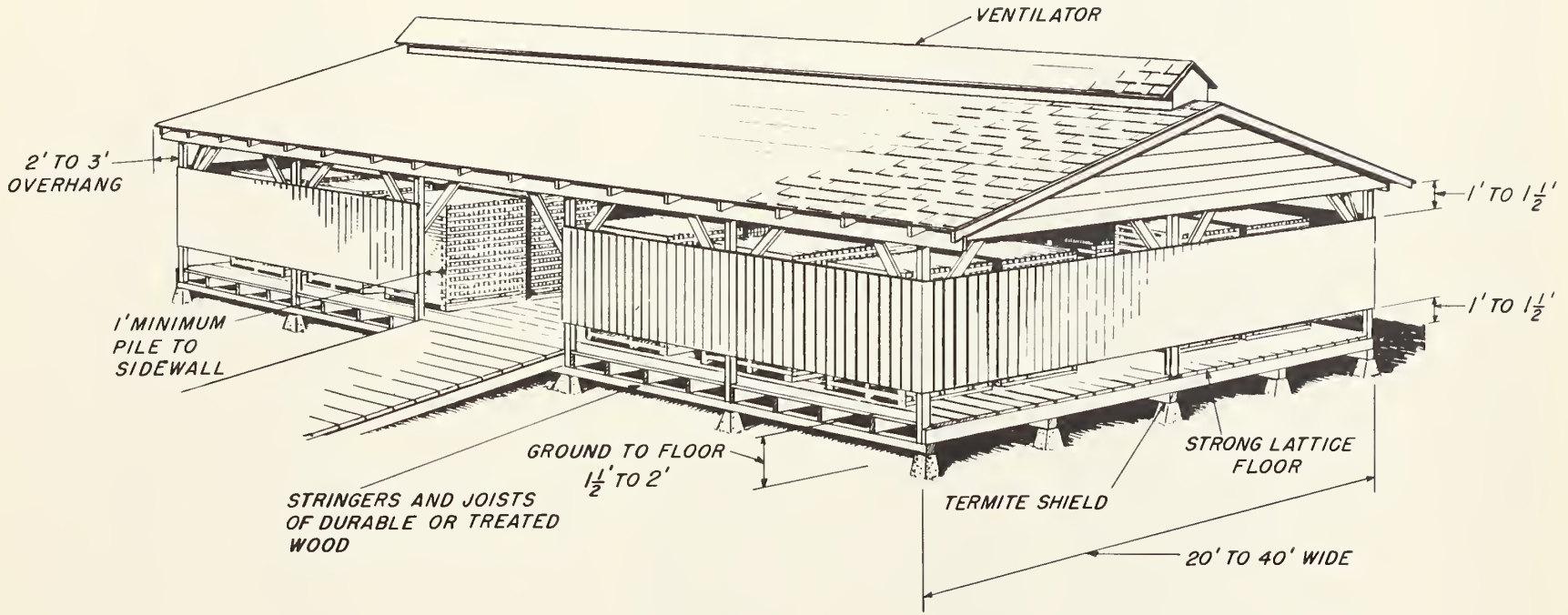


Figure 7.-- Air-drying shed for hickory handle stock.

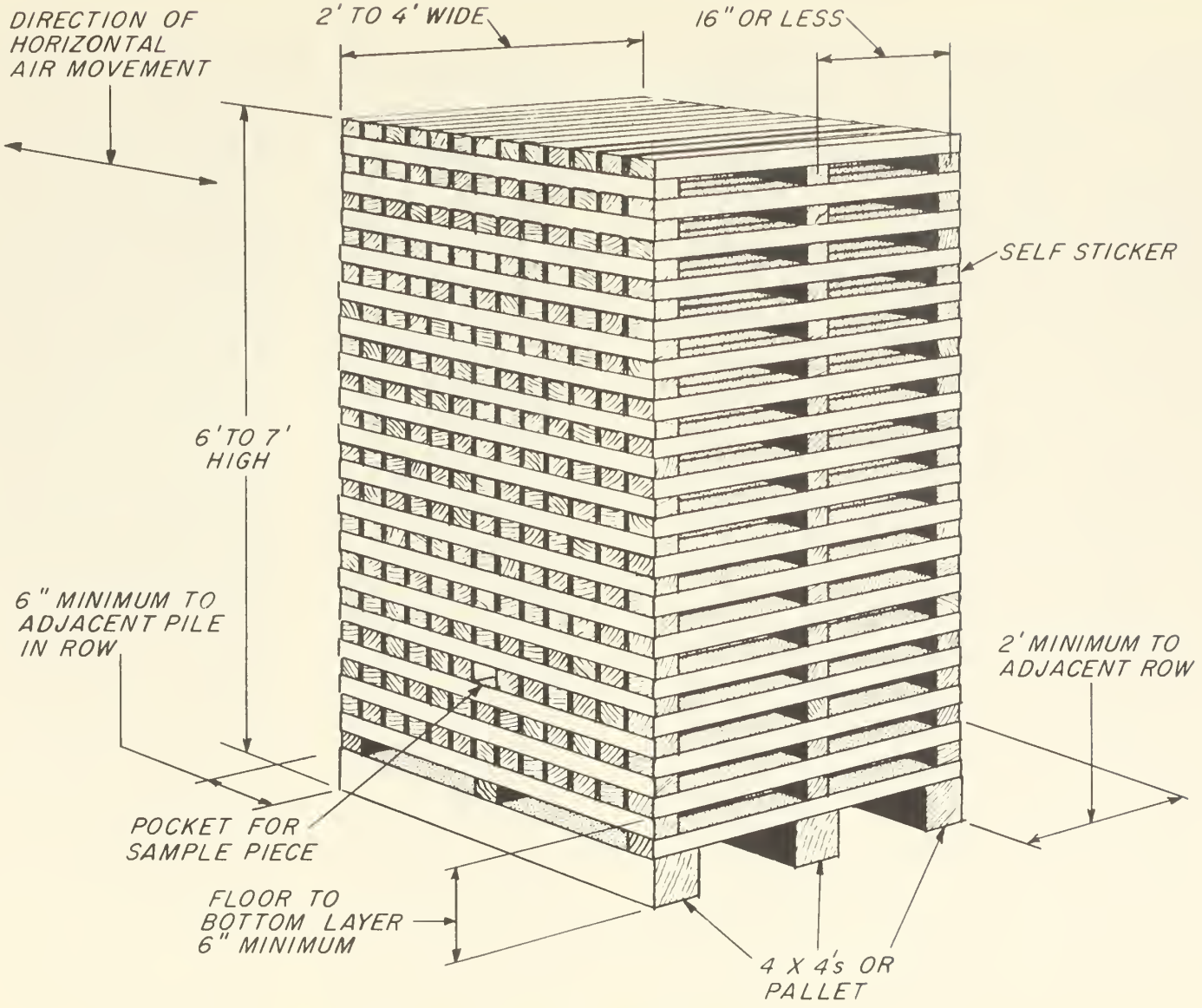

DIRECTION OF HORIZONTAL AIR MOVEMENT
2' TO 4' WIDE
16" OR LESS
SELF STICKER
6' TO 7' HIGH
6" MINIMUM TO ADJACENT PILE IN ROW
2' MINIMUM TO ADJACENT ROW
POCKET FOR SAMPLE PIECE
FLOOR TO BOTTOM LAYER 6" MINIMUM
4 X 4's OR PALLET

Figure 8.--Method of piling hickory handle stock for air drying.

One group of small blanks ($1\frac{1}{2}$ by 2 by 24 inches in dimension) air dried to 20 percent moisture content in 15 days of summer and early fall weather. Drying to 17 percent took an additional 15 days. During winter and early spring, a similar group of small blanks took 110 days to dry from 48 percent to 18 percent moisture content. Another group of small blanks was dried in a kiln at temperatures and relative humidities approximating average summer conditions. Drying time to 20 percent moisture content was 14 days. Air-drying time for these small handle blanks thus varied from 14 to 110 days.

One group of large handle blanks ($2\frac{1}{2}$ by $3\frac{1}{2}$ by 24 inches in dimension) without end coatings air dried from 48 percent to 20 percent in 72 days of late winter and early spring weather. Another group of large blanks, end coated with paraffin, air dried in colder than average spring weather from 54 to 20 percent moisture content in 105 days. The large handle blanks in the first test had slightly excessive end check penetration. End coating appears advisable, therefore, in air drying any hickory item over 2 by 2 inches in cross section.

In spite of fast drying above 20 percent moisture content in the summertime, it is not practical to dry handle stock down to conditions suitable for ultimate use by air drying alone. For example, in the pilot test at Mississippi State College the total air-drying time was about 290 days. The wood still had an average moisture content of 17 percent, which is higher than desirable for handle stock.

Drying Samples

The lack of any consistent, year-round relationship between drying time and moisture content emphasizes the need for using sample pieces to determine when air-dried stock is ready for kiln drying. Such samples would enable an independent handle-blank producer to state with reasonable accuracy the actual moisture content of partially air-dried stock when it is shipped to a handle manufacturer. Sample pieces should be cut from the same stock as the blanks being air dried. They do not need to be free from small defects. Samples containing heartwood should be included if the stock contains heartwood.

At the time blanks are cut to length, select sample pieces. These sample pieces should be cut 9 to 14 inches longer than the blanks will be. This extra length is necessary to provide material for cutting two 1-inch moisture sections. These 1-inch sections are taken at least 6 inches back from each end of the piece, leaving the sample the same length as the blanks. (Sections are used to determine the moisture content of the sample blank.) The two sections should be weighed together on a gram-weighing scale immediately after cutting. Accuracy should be to the closest one-tenth of a gram. The sample blanks should be weighed at the same time, and accuracy should be to the closest one-hundredth of a pound. The sample blanks should have the same end treatment, either coated or uncoated, as the blanks being dried. The moisture sections then should be ovendried at 214° to 221° F. until they come to a constant oven-dry weight.

Moisture content of the sections should be calculated according to formula 1:

(1) Moisture content of sections in percent =

$$\frac{\text{weight at time of test (grams)} - \text{ovendry weight (grams)}}{\text{ovendry weight (grams)}} \times 100$$

The ovendry weight of each sample blank should be calculated according to formula 2:

(2) Ovendry weight of sample blank in pounds =

$$\frac{\text{weight at time of test (lbs.)}}{100 + \text{moisture content of matching sections (percent)}} \times 100$$

From time to time during the course of air drying, the moisture content of the sample can be obtained by weighing the sample and calculating the moisture content by formula 1, using pounds in place of grams. It is helpful in judging when the stock will be dry to keep a graph of moisture content as a function of drying time. General information on sample selection and procedure is given in a U. S. Forest Products Laboratory report (12).

Kiln Drying

The U. S. Forest Products Laboratory has developed kiln schedules for use in drying hickory green from the saw. These schedules can also be used for the finishing of air-dried stock. To achieve drying times comparable to those obtained experimentally and to fully control pinking, however, commercial kilns must have adequate air circulation, and the temperature and relative humidity must be uniform throughout the kiln. Such conditions are best achieved in a modern forced-circulation kiln (13). The stock must be piled to make good air circulation possible, and the kiln operator must have exact knowledge of the moisture content of the hickory.

Piling

For cross circulation kilns, the type of piling shown in figure 8 can be used. The blanks in each pile should be laid so that the air moves parallel to the crossers and across the "solid" layers. A small space should be left between blanks. In the middle of a truckload, the sticker spaces of one pile may not be level with the spaces of another pile, so a space of about 6 inches should be left between the piles to assist cross circulation. In natural draft and some external blower kilns, flues must be made in the loads. In addition, a space of about $1\frac{1}{2}$ to 2 inches should be left between blanks in each layer.

Kiln trucks should have a solid floor or frame to support the blanks. A solid floor is satisfactory for cross circulation kilns but not for other types. In natural circulation kilns, the stock should be at least 18 inches above the heating coils to avoid high temperatures from direct radiation.

Great care should be used in stacking handle blanks to prevent warping. All crossers should be directly alined above each other and above a solid support. If the stock contains considerable variation in thickness, only pieces of the same thickness should be included in a layer.

End Drying versus End Coating

In short stock, like handle blanks, end drying is important. Much of the moisture leaves the piece from the end-grain surfaces. If the stock is end coated, end drying cannot take place. The kiln schedules given in this report have been designed for use without end coatings. The initial kiln conditions are mild to prevent formation of severe end checks. Intermediate conditions have been gaged to prevent deep end-check penetration. The objectives were average end-check penetration of 0.5 inch or less and maximum end-check penetration of 1 inch or less. End checks of this depth would be removed in normal trimming operations. If less end checking is desired, still milder kiln conditions should be used during the first and the second steps, or else a good end coating should be used.

Drying Samples

The control of moisture content by samples is very important in kiln drying to control both pinking and end checking. The method described under, "Air Drying," can be used, but the general report on kiln samples (12) should be consulted by kiln operators. Most of the kiln samples should be selected from the slowest drying stock, that is, the wettest and heaviest stock. A few lightweight samples should be included to avoid overdrying. About 20 kiln samples should be used per charge while the operator is becoming familiar with the fast and slow drying parts of the kiln and the relative drying rates of different types of stock. Changes in kiln conditions should be governed by the average moisture content of the wetter half of the samples. After the operator gets to know the stock and the kiln, the number of samples can be cut to one fast drying and five slow drying samples. The slow drying samples should be placed in the slowest drying parts of the kiln, the fast drying sample in the fastest drying part.

An alternative method for determining the moisture content of well air-dried stock is to use an electric moisture meter. At least 30 blanks should be tested. The five wettest blanks and the driest blank should be weighed individually. Their ovendry weights should be calculated by the regular formula. The samples then can be placed in the load with the other material being dried, after having been properly marked as sample material. From time to time during the drying, the samples should be weighed. Using the calculated ovendry weights and the current weights of the different samples, moisture content values can be determined.

Kiln-Drying Schedules

The principal defects to be avoided by proper kiln schedules for hickory handle stock are pinking and end checking. Surface checking does not occur to any great extent in narrow items if drying conditions are controlled to

limit end checking. Warping occurs in long handles, but kiln conditions cannot be adjusted much to influence it. Stock that is prone to warping should be very carefully stickered at 12-inch intervals and weighted down.

Small handle blanks.--The kiln schedules shown in table 2 have been developed for small handle blanks and dimension stock 2 by 2 inches in cross section and smaller.

Table 2.--Kiln schedules for small hickory blanks

Moisture content	Temperature			Relative humidity	Equilibrium moisture content
	Dry bulb	Wet bulb	Wet-bulb depression		
Percent	°F.	°F.	°F.	Percent	Percent
NONPINKING SCHEDULE					
100 to 60	105	101	4	87	17.5
60 to 40	105	100	5	83	16.2
40 to 30	105	92	13	60	10.3
30 to 20	105	80	25	34	6.1
20 to 8	115	79	36	20	3.9
PINKING-NO-DEFECT SCHEDULE					
100 to 60	130	127	3	91	18.8
60 to 40	130	126	4	89	17.2
40 to 30	130	120	10	73	12.1
30 to 20	150	121	29	42	6.0
20 to 8	180	135	45	30	3.8

These schedules were developed with $1\frac{1}{2}$ by 2- by 24-inch handle blanks with uncoated ends. End checking occurred but was limited to an average penetration of 0.5 inch and a maximum penetration of 1.0 inch. Pinking under the nonpinking schedule was either totally absent or restricted to a slight amount of pinking in the inner one-third of the piece.

Since drying time will vary according to cross section and length, the various sizes should be segregated as much as possible. The time for changing kiln conditions should be based on the average moisture content of the wetter half of the kiln samples. Most sapwood and mixed sapwood-heartwood handle stock can be started from the green condition on the second step of the schedules. If a considerable amount of heartwood with moisture content over 60 percent is included in the charge, the kiln should be started on the first step of either schedule. Stock that has been air dried only a short time should be started on the second step of the appropriate schedule. The kiln should run

about 24 hours on each step until the average moisture content of the controlling samples coincides with the moisture content of the schedule. After that, the moisture content of these samples should govern kiln changes. Partially air-dried stock between 30 and 20 percent moisture content may be started at 10° F. wet-bulb depression, but the initial temperature should be 105° F. if pinking is to be avoided and 130° F. if pinking is no defect. Stock that has been air dried to 20 percent moisture content or less may be started on the next to the last temperature step of either schedule using a 20° F. wet-bulb depression. After the moisture content has been accurately determined, the stock may be changed to the conditions called for by the schedule.

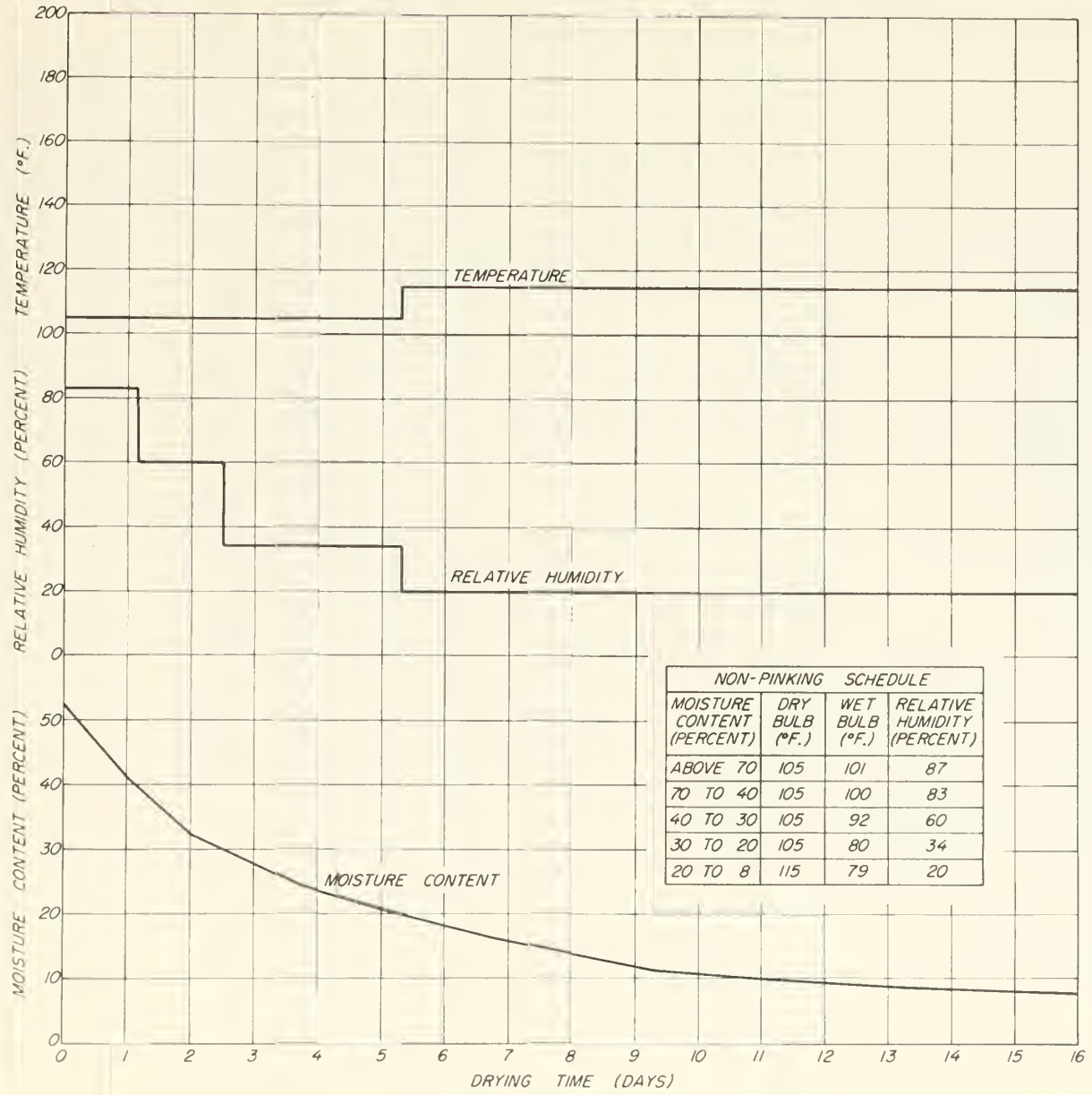
When the driest sample comes to a moisture content equal to 1 percent below the desired average, the kiln conditions should be changed to an equilibrium moisture content (EMC) the same as the moisture content of the driest sample. For instance, if the desired average moisture content is about 8 percent and the minimum and maximum individual values permitted are 7 and 10 percent respectively, the kiln should be changed to 7 percent EMC conditions when the driest sample reaches that moisture content. This condition should then be held until the wettest sample is down to 10 percent moisture content. All of the material will then fall between 7 and 10 percent moisture content. A 7 percent EMC condition is obtained by a wet-bulb depression of 23° F. at both 115° and 180° F. dry-bulb temperatures. For other moisture content values and temperatures, consult a relative humidity-EMC table (10).

The drying curves obtained by the use of the schedules for small stock, $1\frac{1}{2}$ by 2 by 24 inches, from the Southeast are illustrated in figure 9. The drying times were 16 days for the nonpinking schedule and $6\frac{1}{4}$ days for the pinking-no-defect schedule. Somewhat longer drying times should be anticipated in the commercial drying of full charges. The experimental curves should not be used as bases for time schedules because drying time will be longer for each step of the schedule. In the pilot tests at Mississippi State College, kiln charges of 225 to 279 small blanks, 32 to 38 inches long, required 24 days on the nonpinking schedule and 9 days on the pinking-no-defect schedule. A charge previously air dried to 17 percent moisture content required 7 days to complete drying to 8 percent, using the nonpinking schedule.

Large handle blanks.--The kiln schedules shown in table 3 have been developed for large handle blanks more than 2 by 2 inches in cross section.

These schedules were developed with $2\frac{1}{2}$- by $3\frac{1}{2}$- by 24-inch blanks with uncoated ends.

The pinking-no-defect schedule was developed in experiments with pignut, mockernut, and sand hickory from South Carolina. Most of the specimens had low initial moisture content values averaging 52 percent and dried fairly rapidly. A small group of specimens had an initial average moisture content of 67 percent and dried more slowly. Kiln conditions and the drying curves for these 2 different groups of stock are shown in figure 10. End-check penetration was limited to an average 0.6 inch for the fast drying stock and 0.5 inch for the slow drying stock. Maximum end-check penetration was 2.0


TEMPERATURE (°F.)
RELATIVE HUMIDITY (PERCENT)
MOISTURE CONTENT (PERCENT)
TEMPERATURE
RELATIVE HUMIDITY
MOISTURE CONTENT
DRYING TIME (DAYS)
NON-PINKING SCHEDULE
MOISTURE CONTENT (PERCENT) | DRY BULB (°F.) | WET BULB (°F.) | RELATIVE HUMIDITY (PERCENT)
ABOVE 70 | 105 | 101 | 87
70 TO 40 | 105 | 100 | 83
40 TO 30 | 105 | 92 | 60
30 TO 20 | 105 | 80 | 34
20 TO 8 | 115 | 79 | 20

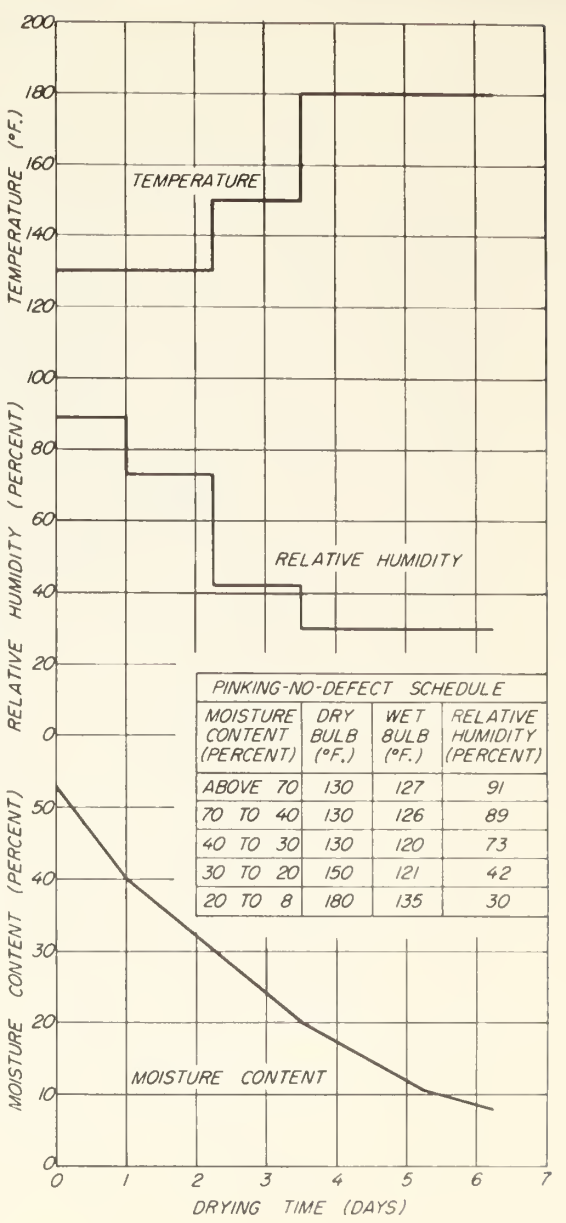

TEMPERATURE (°F.)
RELATIVE HUMIDITY (PERCENT)
MOISTURE CONTENT (PERCENT)
TEMPERATURE
RELATIVE HUMIDITY
MOISTURE CONTENT
DRYING TIME (DAYS)
PINKING-NO-DEFECT SCHEDULE
MOISTURE CONTENT (PERCENT) | DRY BULB (°F.) | WET BULB (°F.) | RELATIVE HUMIDITY (PERCENT)
ABOVE 70 | 130 | 127 | 91
70 TO 40 | 130 | 126 | 89
40 TO 30 | 130 | 120 | 73
30 TO 20 | 150 | 121 | 42
20 TO 8 | 180 | 135 | 30

Figure 9.--Kiln schedules and drying curves for small handle blanks.

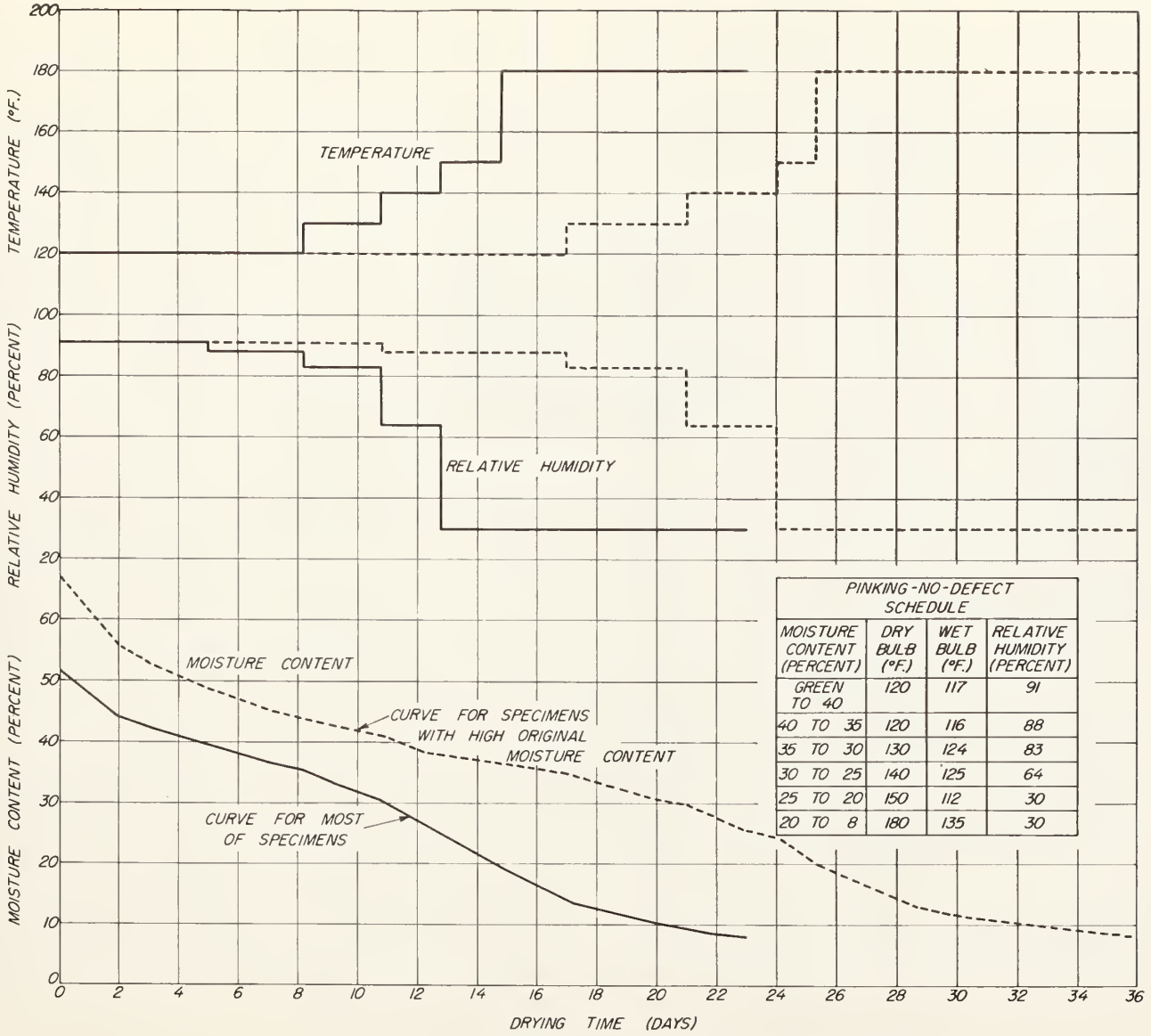

TEMPERATURE (°F.)
RELATIVE HUMIDITY (PERCENT)
MOISTURE CONTENT (PERCENT)
DRYING TIME (DAYS)
TEMPERATURE
RELATIVE HUMIDITY
MOISTURE CONTENT
CURVE FOR SPECIMENS WITH HIGH ORIGINAL MOISTURE CONTENT
CURVE FOR MOST OF SPECIMENS
PINKING-NO-DEFECT SCHEDULE
MOISTURE CONTENT (PERCENT) | DRY BULB (°F.) | WET BULB (°F.) | RELATIVE HUMIDITY (PERCENT)
GREEN TO 40 | 120 | 117 | 91
40 TO 35 | 120 | 116 | 88
35 TO 30 | 130 | 124 | 83
30 TO 25 | 140 | 125 | 64
25 TO 20 | 150 | 112 | 30
20 TO 8 | 180 | 135 | 30

Figure 10.--Kiln schedules and drying curves for large handle blanks.

inches. The fast drying stock required 23 days and the slow drying stock 36 days to dry to 8 percent moisture content. Somewhat longer drying times would be required in commercial drying.

Table 3.--Kiln schedules for large hickory blanks

Moisture content	Temperature			Relative humidity	Equilibrium moisture content
	Dry bulb	Wet bulb	Wet-bulb depression		
Percent	°F.	°F.	°F.	Percent	Percent
NONPINKING SCHEDULE					
Green to 40	105	101	4	87	17.5
40 to 35	105	100	5	83	16.2
35 to 30	105	95	10	69	11.9
30 to 25	105	86	19	46	7.9
25 to 20	105	80	25	34	6.1
20 to 8	115	79	36	20	3.9
PINKING-NO-DEFECT SCHEDULE					
Green to 40	120	117	3	91	19.0
40 to 35	120	116	4	88	17.4
35 to 30	130	124	6	83	14.9
30 to 25	140	125	15	64	10.4
25 to 20	150	112	38	30	4.5
20 to 8	180	135	45	30	3.8

The nonpinking schedule was developed with the easy drying pignut hickory from Mississippi. The experiment with this stock actually used an initial wet-bulb depression of 6°F. and relative humidities somewhat lower in the early stages than those shown in the schedule above. The schedule given in this report was made milder because of the experience with the stock from the Southeast in the pinking-no-defect schedule. The average depth of the end checks in the large pignut hickory blanks cut from Mississippi logs was only 0.4 inch and the maximum penetration 1.4 inches. It is estimated that large hickory handle blanks comparable in drying rate to those from South Carolina might take up to 60 days to dry in commercial kilns using the nonpinking schedule. Air drying, therefore, appears more practical than kiln drying for large blanks if pinking must be avoided.

Large handle blanks that have been partially or fully air dried may be kiln dried by following the general recommendations given under small blanks, but a milder relative humidity should be used until the moisture content of the stock is known.

Modification of Kiln Schedules for Variation of Material

The kiln schedules given above should be mild enough to satisfactorily dry any hickory used for handle stock. If little or no end checking is experienced with hickory from some sources, the schedules can be made slightly more severe by increasing the initial wet-bulb depressions 1° . Extensive experimental work showed that a small increase in wet-bulb depression would give only a small increase in end-check penetration. The relative humidity in the intermediate steps also can be decreased slightly for easy drying stock.

The slightly lower relative humidities suggested above were used with pignut hickory stock from Mississippi. Large handle blanks were dried by the nonpinking schedule in 45 days and by the pinking-no-defect schedule in 16 days. In the pilot tests of schedules for small handle blanks at Mississippi State College, initial wet-bulb depressions of 6° F. were used.

The specimen material from 2 of the 16 logs from the Southeast was very prone to surface checking and deep end-check penetration. Specimens from these logs developed checks during air drying and during kiln drying under the mildest conditions. In the opinion of the author, this type of material is not present to any great extent in the ordinary run of hickory handle material. Only 2 percent of the pieces in each of the three different bark types in the Mississippi pilot test (1) surface checked. If some commercial lots of handle stock give evidence of having a larger percentage of pieces prone to checking, the schedules suggested above should be modified by reducing the temperature or decreasing the wet-bulb depression.

In general, the material from five very old shagbark hickory trees included in the experiments was slower to dry and more prone to checking than the second-growth hickory of Mississippi and the forest-grown hickory from South Carolina. The sapwood material and the outer heartwood dried almost as readily as the slower drying specimens of the other hickories. The inner heartwood was much wetter and much slower drying. It end checked badly on nonpinking schedules and honeycombed on the pinking-no-defect schedule. For such old-growth material, the kiln temperature should be kept below 130° F. until the moisture content is down to 20 percent for small blanks or 15 percent for large blanks.

Control of Pinking

In developing the kiln schedules, the Laboratory carried out extensive research on the effects of temperature, relative humidity, and time on the development of the pink color. Color-test slats were prepared to show the color of the wood $\frac{1}{2}$ inch below one of the wider surfaces of each blank. The color of these slats was evaluated by an instrument that uses a photoelectric cell. Instrument readings were converted to pinking values through a simple formula. The following discussion gives the main findings. More details are given in another report (4).

Hickory becomes considerably pinked upon drying at temperatures above 105° F. Moderate pinking occurs in the range of 105° to 120° F., and severe pinking occurs above 120° F. In some cases use of low relative humidities gave less pinking than higher relative humidities, but, in general, all temperatures above 120° F. gave severe pinking regardless of relative humidity. The length of time at temperatures above 105° F. has some effect on pinking, but at temperatures of 105° F. or below, prolonging the time does not bring about pinking. The critical moisture content below which pinking does not occur appears to be in the neighborhood of 15 percent.

The comparative amounts of pinking in matched test groups of small handle blanks dried under different conditions are shown in table 4. The pinking value of absolutely unpinked hickory is slightly less than 0.100. The lowest pinking value obtained in any of the tests was 0.096 for one unmatched group dried at a constant temperature of 105° F. The values of 0.102, 0.106, and 0.108 in table 4 are slightly higher because of very slight pinking in the cores of the blanks. The shells of these blanks were free of pinking. This degree of pinking should be permissible, since the inner cores would not be exposed in turning. The pinking value of 0.143 obtained in the pinking-no-defect schedule represents heavy pinking. Pinking values up to 0.185 have been obtained under some conditions, but any pinking value above 0.130 may be regarded as severe.

Table 5 further illustrates the care that must be taken in kiln drying even well air-dried stock if pinking is to be avoided. The small handle blanks for which these data were obtained were partially dried under simulated air-drying conditions of 96° F., 14 percent EMC, and a low rate of air circulation. At 30 percent moisture content, some of the blanks were moved to higher temperatures. The rest of the blanks were changed when they had dried to 20 percent. Severe pinking occurred in all blanks changed at 30 percent moisture content. In the blanks changed at 20 percent, the degree of pinking varied with temperature. Even those finished at 120° F. showed more pinking than is desirable.

The slats changed to high temperatures at 20 percent moisture content had nonpinked margins. Thus, blanks that are rough turned and then thoroughly air dried can be finished in a kiln at temperatures up to 130° F. without pinking the outer shell. The core of the blanks must be brought down to 15 percent moisture content or less before it is entirely free from susceptibility to pinking. In one experiment with large blanks dried at low temperatures to an average of 13 percent moisture content, the cores were wet enough to send the pinking value up to 0.126 when the kiln temperature was changed to 135° F.

If speed in drying is not a major factor, a kiln operator can be more sure of controlling pinking in all parts of his kilns by using temperatures of 100° F. or less, instead of 105° F. Drying time to 20 percent moisture content is not too long at such a temperature. It was $8\frac{1}{2}$ days at 96° F. and 14 percent EMC. Below 20 percent moisture content, however, drying temperatures of 105° to 115° F. are recommended consistent with degree of pinking control and drying-time requirements.

Table 4.--Pinking of small handle blanks dried under different conditions

Method of seasoning	Type of schedule	Temperature in kiln		Pinking value
		Initial	Final	
		°F.	°F.	
Air dried, finished in kiln	Nonpinking	105	115	0.106
	" "	115	115	.102
	Pinking-no-defect	130	180	.122
	" " "	180	180	.126
Kiln dried from green condition	Nonpinking	105	115	.108
	Pinking-no-defect	130	180	.143

Table 5.--Effect of changing partially air-dried hickory handle blanks to different kiln temperatures

Initial seasoning method	Moisture content of stock when changed to kiln drying	Temperature in kiln	Pinking value
	Percent	°F.	
Simulated summer air drying	30	120	0.145
	"	135	.139
	"	150	.148
	"	165	.185
Simulated summer air drying	20	120	.120
	"	135	.126
	"	150	.131
	"	175	.140

One kiln manufacturer[8/] has installed special automatic equipment to dry hickory handle stock with an oscillating kiln schedule and reports complete control of pinking. A constant wet-bulb temperature of 95° F. is set, and the dry-bulb temperature is oscillated daily with a cam. The dry-bulb temperatures used the first few days are generally below 105° F., but during the first 7 days they average just over that figure. Small, rough-turned handle blanks are dried by this method in 2 weeks.

When a pinking-no-defect schedule is used, drying time is one-third to one-half the time required with a comparable nonpinking schedule. This suggests that if handle users could be encouraged to look first for dense hickory and to accept pinked hickory as equal in strength to white hickory, considerable reduction in cost of production could be made. Drying temperatures of 130° F. or higher should be used if uniform coloration is desired.

Dry Storage

Handle stock that has been kiln dried to 8 percent moisture content will absorb moisture again to about 12 percent moisture content if stored in an unheated shed. Since most handles and handled tools are stored and used in warehouses or shops with low humidity during the wintertime, factory storage conditions should be provided to keep the handles at 8 percent. The storage room should be enclosed and have some provision to keep its relative humidity near 42 percent. This can be done fairly simply by providing a small amount of heat during periods of high humidity so as to raise the temperature about 15 degrees above the outdoor temperature (5).

Attention should also be paid to prevention of insect attack during storage. Powder-post beetles attack and severely damage hickory, ash, and oak sapwood during long periods of undisturbed storage. The following simple program is suggested to prevent losses:

1. Burn all refuse and useless sapwood material.

2. Inspect storage and seasoning sheds twice yearly. Sort out and burn material showing evidence of severe beetle attack.

3. Use or sell oldest stock first.

4. Inspect new stock from other sources to prevent introduction of beetles.

5. Kill beetles and eggs in lightly infested stock by heating 1 or 2 hours in a kiln at 180° F. or steaming in a saturated atmosphere for 1½ to 3 hours at 140° F.

8/ Correspondence with J. B. Welch, Standard Dry Kiln Co., Indianapolis, Ind.

More details on control of powder-post beetles are given in another publication (9). If heavy infestations of the beetles are found in the storage shed or nearby areas, write the Division of Forest Insect Research, Forest Service, Washington, D. C., for additional information and advice.

Toughness and Drying Procedures

Hickory is the world's supreme wood for striking-tool handles because of its natural toughness and ability to stand up under rough use. Whether or not the drying procedures covered by this report have any damaging influence on toughness is, therefore, of prime importance. To check on toughness, three separate tests were made. More than 1,000 individual specimens were included in the three tests. The first was on pignut hickory material from Mississippi, the second was on the material included in the Mississippi State College pilot test (1), and the third was on the pignut, mockernut, sand, and shagbark hickory from the Southeast and Kentucky.

For the first two batches of material, the kiln-drying conditions did not lower toughness. Slightly lower toughness was found for the thicker items of hickory from the Southeast and Kentucky when kiln dried by the pinking-no-defect schedules. These differences probably are not important for ordinary handles, since toughness values were still very high and the test breaks were of the tough type. For special large handles in which the very highest toughness is desired, air drying the stock to 20 percent moisture content before kiln drying may be best. Such precautions are not necessary for small handles, in view of the results of the first two tests and the fact that two groups of 4/4 lumber kiln dried with a final temperature of 180° F. in the third test had slightly higher average toughness values than the controls.

LITERATURE CITED

(1) HOPKINS, W. C., and KELSO, W. C., Jr.
1951. Kiln drying of hickory handle stock; Pilot tests of drying schedules. South. Lumberman 182(2285): 40-42.

(2) JOHNSTON, H. R.
1952. Insect control: Practical methods for the control of insects attacking green logs and lumber. South. Lumberman 184 (2307): 37-39.

(3) McMILLEN, J. M.
1950. Coatings for the preservation of end checks in logs and lumber. U. S. Forest Products Lab. Rpt. 1435.

(4) _____
1950. Kiln drying of hickory handle stock. South. Lumberman 181(2273): 292-304.

(5) MATHEWSON, J. S.
1953. Electrically operated wood-element hygrostats for control of moisture fluctuations in lumber stored in closed sheds. U. S. Forest Products Lab. Rpt. 1140.

(6) PECK, E. C.
1950. Air drying of lumber. U. S. Forest Products Lab. Rpt. 1657.

(7) RASMUSSEN, E. F.
1952. A method of seasoning small quantities of lumber. U. S. Forest Products Lab. Rpt. 1608.

(8) SCHEFFER, T. C., and JONES, T. W.
1953. Control of decay in bolts and logs of northern hardwoods during storage. Northeastern Forest Expt. Sta. Paper No. 63.

(9) SNYDER, T. E.
1938. Preventing damage by Lyctus powder-post beetles. Farmers' Bul. No. 1477.

(10) TORGESON, O. W.
1951. Schedules for the kiln drying of wood. U. S. Forest Products Lab. Rpt. 1791.

(11) U. S. FOREST PRODUCTS LABORATORY
1941. Cause and prevention of blue stain in wood. U. S. Forest Products Lab. Tech. Note 225.

(12) U. S. FOREST PRODUCTS LABORATORY
1954. Use of kiln samples in operating a lumber dry kiln. U. S. Forest Products Lab. Rpt. 1607.

(13) _____
1955. List of dry-kiln companies and engineers and consultants in the United States. U. S. Forest Products Lab. Rpt. 1031.

(14) _____
1955. List of manufacturers and dealers for log and lumber end coatings. U. S. Forest Products Lab. Rpt. 1954.

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